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Cover crop, rye residue and in-furrow treatment effects on thrips

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Abstract: Thrips and thrips damage to cotton and peanut plants were compared in plots with in-furrow treatments of aldicarb, phorate and diammonium phosphate (DAP) fertilizer under two tillage regimes with a winter cover of crimson clover and under different levels of rye residue ground cover. Adult and larval thrips numbers were significantly lower in cotton plots following winter crimson clover cultivation compared with no-cover plots in all 3 years. Thrips numbers did not differ with respect to the in-furrow treatments in the clover plots, but in the no-cover plots, they were significantly higher in the untreated control and DAP treatments compared with the aldicarb treatment. Thrips damage was higher in the no-cover than the clover plots except in the aldicarb treatments. Within the cover crop plots, thrips damage was highest in the control and phorate treatments and similar in the DAP and aldicarb treatments. There was an inverse relationship between the amount of rye residue ground cover and thrips density and thrips damage in cotton and peanuts. There was also an inverse relationship between the density of rye residue and damage to peanuts from Bunyaviridae tospovirus. Cotton yield was reduced in the cover crop plots and was not measured in the rye residue and peanut plots. These results suggest that ground cover alone decreases thrips numbers and thrips damage in both cotton and peanuts and that a winter crimson clover cover and an in-furrow treatment of DAP enhanced plant protection from thrips in cotton.

Key words: aldicarb, cotton, crimson clover, DAP, peanuts, rye residue, thrips

1 Introduction

Thrips feeding damage on seedling cotton, *Gossypium hirsutum* L., and peanuts, *Arachis hypogaea* L. can have deleterious effects on growth, including malformation of leaves, reduced leaf area, retarded plant growth, seedling mortality, delayed crop maturity and lower yields (Womack et al. 1981; Cook et al. 2003). However, some researchers have reported no yield benefits from thrips control in cotton (reviewed in Faircloth et al. 2002), in part because plants at times show compensation for the seedling damage, especially longer-season crops that have more time to recover (Sadras and Wilson 1998). In both crops, the dramatic visually observed damage inflicted upon seedlings by thrips and the real yield losses in some cases (Faircloth et al. 2002) have resulted in most growers using prophylactic measures, usually an in-furrow treatment of aldicarb. This treatment is also useful at higher rates for the control of plant parasitic nematodes. However, because aldicarb has lethal and sub-lethal effects on a variety of non-target species (e.g. Jackson and Lam 1989; Mohamed and Adam 1990; Moulton et al. 1996; Parker and Goldstein 2000; Mosleh et al. 2003), an alternative thrips and plant parasitic nematode control option would be desirable.

Management practices such as conservation tillage (All et al. 1992, 1995) and the use of winter cover crops have been found to reduce the density of thrips and thrips damage in cotton (S. C. Phatak, pers. obs.; Manley et al. 2002). Conservation tillage is mainly used for reducing machinery costs and labour, and increasing soil productivity through increases in soil organic matter and water infiltration/availability (Liu and Duffy 1996). The addition of cover crops not only protects the soil from erosive forces but also provides many other benefits to the soil and pest suppression (reviews in Schomberg et al. 2003). Pest suppression may be a result of the increase in the population of beneficial arthropod species found in these systems (McCutcheon et al. 1995; Ruberson et al. 1995; Phatak 1998; Phatak et al. 1999; Tillman et al. 2004), probably by the provision of perennial alternative hosts, food sources, favourable habitats and mating sites than those found in non-cover crop fields. Leguminous cover crops increase available nitrogen through nitrogen fixation and rapid decomposition, supplying nitrogen early in the growing season (reviews in Schomberg et al. 2003), which may increase the vigour of younger and more vulnerable plants, making them more tolerant to feeding injury.

Although the pesticide aldicarb aids in plant establishment and growth (Reddy et al. 1997), the underlying mechanisms that enhance these factors are poorly understood. Starter fertilizers are used for enhancing seedling establishment, early growth and crop uniformity (Bednarz et al. 2000; Toler et al. 2004), but yield response has been variable (Ashley et al. 1974; Touchton et al. 1986; Funderburg 1988; Morris et al. 1989). Cotton growth response to starter solutions has been attributed to phosphorus (Walker et al. 1984; Funderburg 1988), but more recently the growth response of several plants has also been attributed to nitrogen (Toler et al. 2004). We speculated that nitrogen and phosphorus in the starter fertilizer, diammonium phosphate (DAP), along with the additional nitrogen from a leguminous cover crop may enhance plant establishment and growth, and may allow seedlings to better tolerate thrips feeding.

The first objective of this study was to evaluate an in-furrow application of DAP starter fertilizer in conservation tillage cotton planted with a winter crimson clover, *Trifolium incarnatum* L., cover for their combined potential for enhancement of cotton seedling establishment, seedling vigour and the reduction in seedling damage from thrips. Our second objective was to evaluate the influence of various densities of rye residue in cotton and peanuts on thrips density, thrips damage and damage in peanuts caused by the virus, Bunyaviridae tospovirus, for which several thrips species serve as vectors.

2 Materials and Methods

2.1 Conservation tillage with crimson clover and conventional tillage cotton

Dixie crimson clover was planted in late November in the years 2001, 2002 and 2003 in one half of a 1.21-ha field (cover plots) in Tift Co. (Georgia, USA) and the other half (no-cover plots) had winter weeds and conventional tillage. Cover and tillage type treatments were replicated over the 3 years. In late March, 60 kg/ha fertilizer (N:P:K, 3:15:30) was harrowed into the no-cover plots and broadcast over the top of the crimson clover. The clover was killed in mid-April by broadcast application of glyphosate.

All treatment plots were in-row sub-soiled to a depth of 30 cm prior to planting the cotton. Deltapine 5415 RR, was planted at 1.5 kg/ha in a split-plot design consisting of 16 cover subplots in a 60 × 108 m area and 16 no-cover subplots in a 60 × 108 m area in late April 2002 and early May 2003 and 2004. The randomly assigned in-furrow treatment subplots (15 × 27 m) replicated four times consisted of: (1) control = cotton seed only, (2) diammonium phosphate (DAP) (N : P : K, 10 : 34 : 0), at 2.34 l/ha on treated area of a 25.5-cm band, (3) aldicarb (Temik® 15 G) and (4) phorate (Thimet® 20 G) (Bayer Crop Science, Research Triangle Park, North Carolina, USA) each at 0.53 kg/ha. In late May each year, the entire 1.21-ha area was broadcast-sprayed with glyphosate to kill weeds.

Each week for 3–4 weeks, until the cotton was at the five-leaf stage, 10 cotton seedlings chosen from the centre of each plot were assayed for thrips and thrips damage. Thrips were collected from sampled seedlings by pulling the seedling and agitating the leaf and tip area in 70% ethanol solution. The thrips were sifted from the ethanol using a fine-mesh screen and the numbers of adults and larvae were counted using a stereomicroscope. Adults were identified to the species level, but as the larvae are more difficult to identify only the total numbers were recorded. We assayed per cent leaf damage and whether the plant terminal had damage. For the former, the classification used was: 1 = 0–20% leaf damage, 2 = 21–40%, 3 = 41–60%, 4 = 61–80% and 5 = 81–100%. Terminal damage was assigned a '1' and no terminal damage was assigned a '0' and then added to the leaf damage for an estimate of total plant damage. Because greenhouse and small-plot studies indicate that crimson clover fields are good reproductive habitats for the root-knot nematode species, *Meloidogyne arenaria* (Timper et al. 2003), we sampled plots for this species to determine potential increases in nematode populations. *Meloidogyne arenaria* was sampled from soil on 1 May, 27 August and 8 October in 2002, on 16 May and 25 August in 2003, and on 3 June and 23 August in 2004. We used Levene's test, which rejects the hypothesis that variances are equal when the absolute value of the residuals has a significant effect on the factors in the model. To equalize the variance associated with the mean number of thrips (Levene's test <0.05), we ln-transformed the number of thrips (Levene's test > 0.16). Levene's test indicated that treatment variances for root-knot nematode mean values were not different ($P > 0.07$). The influence of cover and treatment on ln-transformed number of thrips, number of plants and yield, and untransformed number of root-knot nematodes was tested using ANOVA (SAS Institute Inc. 1998). Mean values were separated with Tukey's LSD with $P < 0.05$ considered significant. Chi-squared analysis was used to test the influence of cover and treatment on plant damage caused by thrips (SAS Institute Inc. 1998).

In 2002, 12 rows per plot was measured in a cotton stand with a vertical (1 m length) transect crossing the rows along the centre of the plot. The first four rows of cotton of each plot was defoliated on 10 September and harvested by machine in 2002 (94.5 m^2) to estimate seed-cotton yield.

2.2 Comparison of rye residue density

Peanut (var. Georgia Green) was planted on 3 May 2002, cotton (var. Deltapine 555) was planted on 30 April 2002 and cotton (var. Deltapine 444) was planted on 7 May 2003 in 16, 1.8 × 15.2 m plots with residue treatments replicated four times. Fertilizer, 60 kg/ha (N:P:K, 3:15:30) was harrowed into the plots prior to planting. Rye residue was hand-applied on 6 May and the plots were subsequently irrigated. Residue treatments were classified as: no residue, low residue (1/4 bale = 3.40 kg), moderate residue (1/2 bale = 6.80 kg) and high residue (1 bale = 13.60 kg). The low residue treatment was omitted in 2003. Peanut plants were assayed for the number of thrips on 13 May, 20 May, 28 May and 3 June, and larvae and adults were combined. Cotton plants were assayed for the number of thrips on 13 May, 20 May and 28 May in 2002, and 23 May and 30 May in 2003. Thrips were counted as in the cover crop study. Thrips damage was assayed on 30 May based on a scale of 1–10 in peanuts and 1–5 in cotton by walking and estimating per cent damage per 30.5-m row. Plant damage caused by Bunyaviridae tospovirus was determined on 30 May as in Culbreath et al. (1997). The effect of replication and residue on the number of adult thrips, ln-transformed larval thrips, thrips damage and Bunyaviridae tospovirus damage was tested with ANOVA (SAS Institute Inc. 1998). Mean values were separated using Tukey's LSD with $P < 0.05$ considered significant.

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3 Results

3.1 Conservation tillage with crimson clover and conventional tillage cotton

Two species of adult thrips, *Frankliniella occidentalis* (Pergande) and *Frankliniella fusca* (Hinds) in approximately equal numbers were captured from seedling cotton during the 3 years. There was a significant effect of year on the number of adult and larval thrips (table 1). Adult and larval numbers were significantly higher in 2002 (5.44 ± 7.30 and 1.71 ± 2.84, respectively) than in 2003 (2.48 ± 5.75 and 1.23 ± 2.39, respectively) and 2004 (0.33 ± 1.05 and 0.53 ± 0.90, respectively). There was a significant effect of cover on adult and larval thrips but this depended on the in-furrow treatment (table 1). There were significantly more adult and larval thrips in the no-cover than the cover plots (fig. 1a,b). The aldicarb and phorate treatments had significantly fewer adult and larval thrips than the other treatments within the no-cover plots, whereas their numbers were similar across the treatments in the cover plots (fig. 1a,b).

There was a significant interaction between cover and treatment for adult *F. fusca* and a significant effect of cover and treatment on adult *F. occidentalis*. Adult *F. fusca* were significantly more abundant in the no-cover than the cover plots, and their density in these plots were higher in the DAP and control than in the aldicarb and phorate treatments (fig. 2a; cover × treatment: MS = 7.36, d.f. = 3, $F = 15.71$, $P < 0.001$). Adult *F. occidentalis* were also significantly more abundant in the no-cover than the cover plots (fig. 2b; cover: MS = 20.58, d.f. = F = 41.72, $P < 0.001$), but their density was significantly higher in the aldicarb and phorate than the DAP and control treatments (fig. 2b; MS = 2.80, d.f. = 3, $F = 5.68$, $P < 0.002$).

Plant damage caused by thrips was significantly higher in the no-cover than the cover plots for all in-furrow treatments except aldicarb (fig. 3a; $\chi^2 = 122.14$, d.f. = 3, $P < 0$ .001). In the no-cover plots, aldicarb treatment had the lowest damage, followed by phorate and then by the non-treated control and by DAP (fig. 3b). Within the cover plots, overall thrips damage was highest in the control treatments, followed by phorate, then DAP and then aldicarb (fig. 3b). Overall plant stand was significantly higher in the no-cover (6.7 ± 2.37 plants/m) than the cover (3.6 ± 2.12 plants/m) plots (cover by treatment: MS = 41.75, d.f. = 3, $F = 11.48$, $P = 0.000$). Plant stand was significantly lower in the phorate treatment in the no-cover (4.16 ± 1.92 plants/m) plots compared with the aldicarb (8.02 ± 1.62 plants/m), DAP (7.41 ± 1.87 plants/m) and control (7.25 ± 1.95 plants/m) treatments. Plant stand within the cover plots was significantly higher for the aldicarb (4.90 ± 2.35 plants/m) and DAP (3.79 ± 1.95 plants/m) treatments than the control (2.85 ± 1.77 plants/m) and phorate (2.88 ± 1.69 plants/m) treatments. There were no significant effects in the cover by treatment interaction (d.f. = 3, MS = 0.53, $F = 0.13$, $P = 0.941$) on cotton yield. Overall, significantly higher seed-cotton yields were found in the aldicarb (2394.16 ± 314.34 kg/ha) than the control (2023.81 ± 385.26 kg/ha) and phorate (1984.13 ± 314.34 kg/ha) treatments (d.f. = 3, MS = 24.45, $F = 6.03$, $P = 0.004$), and in

Table 1. ANOVA *testing the effect of year (2002, 2003 and 2004), date, cover (crimson clover, with strip tillage and conventional tillage), in-furrow treatment (control, diamonium phosphate, aldicarb and phorate), replication of treatment within cover (4), and the interaction between cover and treatment on the number of ln-transformed adult and larval thrips collected from cotton seedlings*

Source	d.f.	MS	F-value	P-value
Adults				
Year	2	85.23	119.68	< 0.001
Date	3	21.69	30.46	< 0.001
Rep	3	0.65	0.91	0.435
Cover	1	52.75	74.07	< 0.001
Treat	3	7.10	9.97	< 0.001
Cover × Treat	3	6.56	9.21	< 0.001
Error	303	0.71		
Larvae				
Year	2	5.84	10.48	< 0.001
Date	3	2.03	3.64	0.013
Rep	3	0.29	0.52	0.671
Cover	1	43.88	78.70	< 0.001
Treat	3	8.02	14.38	< 0.001
Cover × Treat	3	4.01	7.20	< 0.001
Error	303	0.56		

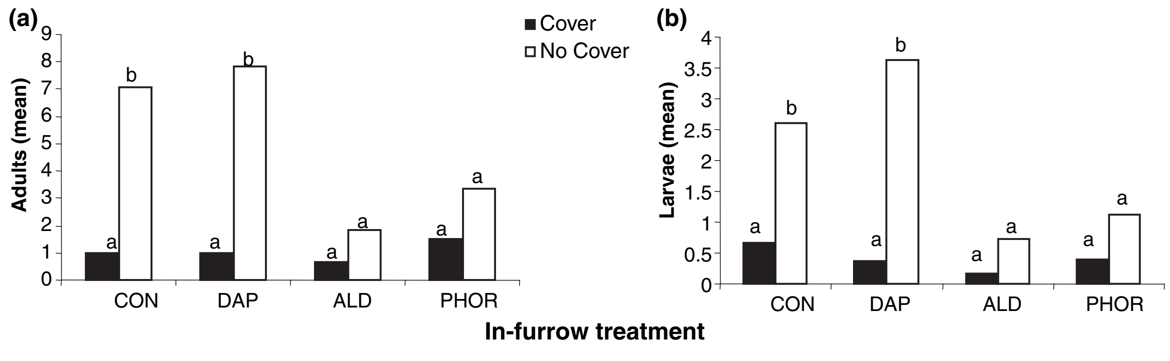

Fig. 1. Mean number of adult (a) and larval (b) thrips per 10 seedlings in no-cover and cover plots with in-furrow treatments of control (CON), DAP, aldicarb (ALD) and phorate (PHOR). Tukey's LSD: Different letters above bars are significantly different at $P < 0.05$

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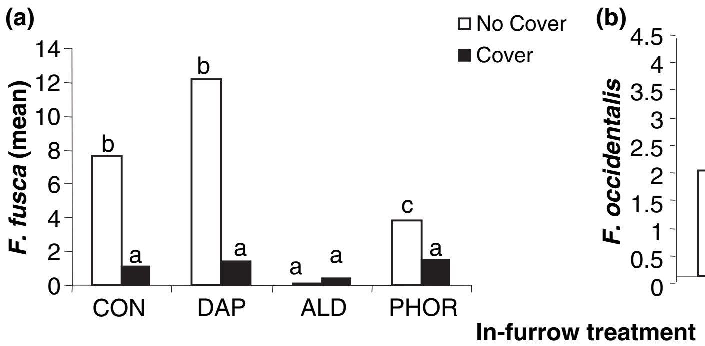

Fig. 2. *Mean number of adult (a)* F. fusca *(b)* F. occidentalis *per 10 seedlings in no-cover and cover plots with in-furrow treatments of control (CON), DAP, aldicarb (ALD) and phorate (PHOR). Tukey LSD: Different letters above bars for* F. fusca *are significantly different at P < 0.05, and different letters above bars within field type for* F. occidentalis *are significantly different at P < 0.05*

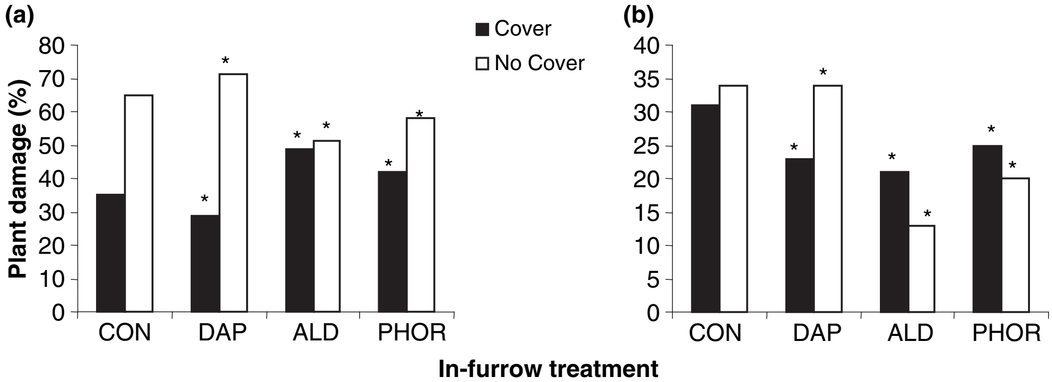

Fig. 3. *Per cent plant damage from thrips in cover and no-cover plots with in-furrow treatments of control (CON), DAP, aldicarb (ALD) and phorate (PHOR). In (a), cover and no-cover bars within furrow treatments sum to 100%, and in (b), bars across treatments within cover or no-cover sum to 100%. Asterisks above the bars indicate significant deviation from expectation at P < 0.05*

the no-cover (2235.99 ± 317.52 kg/ha) than the cover-crop (2043.65 ± 353.51 kg/ha) plots).

There was a significant interaction between cover and treatment on the density of *M. arenaria* (MS = 277.78, d.f. = 3, F = 4.81, P < 0.003). In all 3 years, the density of *M. arenaria* was low, but in the no-cover plots, their density was significantly higher in the aldicarb than the DAP treatments (8.14 ± 15.69 and 1.11 ± 3.20, respectively).

3.2 Comparison of rye residue density

Residue had a significant effect on the number of thrips in peanut (MS = 400.60, d.f. = 3, F = 5.35, P < 0.003), and in cotton (adults: MS = 41.40, d.f. = 3, F = 5.07, P < 0.004; larvae: MS = 14.83, d.f. = 3, F = 15.31, P < 0.001). Significantly more adult and larval thrips were found in the no-residue plots than in the moderate- and high-residue plots (tables 2 and 3). Residue also had a significant effect on thrips damage in peanut (MS = 16.76, d.f. = 3, F = 76.58, P < 0.001) and cotton (MS = 10.07, d.f. = 3, F = 201.17, P < 0.001), and the level of damage (MS = 695.58, d.f. = 3, F = 16.66, P < 0.001). Significantly more thrips and Bunyaviridae tospovirus damage was found as the density of residue decreased (tables 2 and 3).

4 Discussion

In this study, we found that the first-year conservation tillage cotton with a winter crimson clover cover crop and an in-furrow DAP treatment reduced thrips numbers and seedling damage in dry-land cotton as well as aldicarb and phorate. Furthermore, yields and plant stand did not differ between aldicarb and DAP treatments overall, although yields for no-cover (2235.99 kg/ha) and cover plots (2043.65 kg/ha) were significantly different. Increased yields can be obtained in cotton using cover crops and conservation tillage (Raper et al. 2000; Bauer and Roof 2004), and as soil organic matter and nitrogen accumulates in these systems over time, yields would also probably improve.

The relationship between high thrips numbers and high plant damage in conventional plots and the low thrips numbers and low plant damage in the cover plots suggests that lower damage in cover plots is due to low thrips numbers. However, differences in damage levels across treatments within the cover crop plots with similar numbers of thrips also suggest that the in-furrow treatments of DAP, aldicarb, and to a lesser extent, phorate did provide additional benefits to the plants compared with the controls. It is interesting that *F. fusca* and *F. occidentalis* adults responded differently

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Table 2. *Mean ± SD number of thrips per 10 peanut plants per plot (N = 16), thrips damage (1–10 in 30.5 m rows) and* Bunyaviridae tospovirus *damage in peanut plots with various levels (none, low, moderate and high) of rye residue*

Source	Thrips	Thrips damage	Bunyaviridae tospovirus damage
No residue	21.56 ± 12.50 a	9.27 ± 0.34 a	53.8 ± 8.85 a
Low residue	18.25 ± 14.25 ab	7.82 ± 0.74 b	45.3 ± 11.28 a
Moderate residue	11.50 ± 10.19 b	6.15 ± 0.72 c	30.3 ± 15.20 b
High residue	11.63 ± 8.61 b	4.55 ± 0.34 d	25.3 ± 8.14 b

Real mean values are reported, but log-transformed numbers were used in the statistical analyses. Different letters in columns are significantly different at P < 0.05.

Table 3. *Mean ± SD number of thrips per five cotton plants per plot (n = 16 for no, moderate, and high residue and n = 12 for low residue), thrips damage (1–5 in 30.5 m rows) with various levels (none, low, moderate and high) of rye residue*

Source	Adult thrips	Larval thrips	Thrips damage
No residue	5.30 ± 4.11 a	38.35 ± 28.38 a	4.28 ± 0.26 a
Low residue	2.83 ± 4.45 b	7.92 ± 6.57 b	3.54 ± 0.40 b
Moderate residue	2.50 ± 2.16 b	5.15 ± 4.12 b	2.94 ± 0.40 c
High residue	2.05 ± 2.31 b	5.00 ± 4.77 b	2.47 ± 0.39 d

Real mean values are reported, but log-transformed numbers were used in the statistical analyses.

to the treatments within the no-cover plots. While *F. fusca* density was higher in the control and DAP treatments, the density of *F. occidentalis* was higher in the aldicarb and phorate treatments. This is similar to what we have found in a 2005 study of the mechanism(s) underlying thrips responses to the different ground covers and treatments (D. M. Olson unpubl. data). It is possible that only *F. occidentalis* was directly affected by the treatments and that *F. fusca* was affected by the presence of *F. occidentalis*. Further studies are needed to understand this species-specific response to cover and in-furrow treatments.

The reduced numbers of thrips in the cover crop plots may be due to the clover plants serving as a trap crop for thrips as the clover had been killed only 2 weeks prior to planting. However, the residue tests indicated a significant influence of the density of rye residue on thrips colonization and plant damage. Thus, increasing field cover alone reduces thrips numbers and resultant damage in both peanut and cotton. Several studies have shown that thrips numbers were substantially reduced in greenhouses when ultraviolet-absorbing plastic covered the greenhouse compared with controls (Antignus et al. 1996, 2000; Costa and Robb 1999; Costa et al. 2002), and when black plastic was placed under peanuts (D. D. M. Olson, unpubl. data). It has been suggested that thrips reductions result from interference with visual cues and/or behavioural responses to UV light, which many insect species use to orient to host plants (reviewed in Costa et al. 2002). In addition, reduced tillage alone has a significant effect on reducing thrips numbers in cotton compared with plots with tillage (All et al. 1992, 1995). The effects of reduced tillage and cover crop or residue on thrips numbers were confounded in our study, suggesting that it would be necessary to determine the relative importance of cover crop or residue and amount of tillage on reduction in thrips numbers in these systems.

Differential predation may have also contributed to the reduced numbers of thrips in the conservation tillage-cover crop field compared with the conventional field. Several beneficial predator species are usually more abundant in conservation tillage with crimson clover cover than conventional tilled fields with no clover (McCutcheon et al. 1995; Ruberson et al. 1995; Phatak 1998; Phatak et al. 1999; Tillman et al. 2004), so the differences in thrips numbers that we found may be due to predation by these species. Nichols et al. (2000) found that vineyards with summer cover crops had significantly fewer thrips than vineyards with bare ground. They attributed this to higher predation rates in the vineyards with summer covers because of the significantly higher predator densities also found in these systems. However, as indicated by this study, the reductions in thrips numbers could also have been affected by the ground cover compared with the bare ground in the vineyard.

Seed-cotton yields were higher in no-cover plots across treatments despite the increased damage caused by thrips in these plots, possibly because of plant compensation for thrips damage and the relatively low plant stand in the no-cover plots. The lower cotton yields found in the cover plots may have arisen because the needed nutrients were still tied up in the clover residue or in the developing weeds. Although the clover stand was less than optimal, mainly because of inadequate water and weed control, it is possible to get a dense and healthy clover stand in the first year. Better stands and possibly an earlier killing of the clover may have improved upon the results found in this study,

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suggesting that proper management of the cover crop may be needed to use this strategy effectively.

Root-knot nematode populations were low and remained low throughout the study, but because crimson clover is a good reproductive plant for these species their numbers could increase in these systems. Thus, when using crimson clover as a cover crop, close monitoring of root-knot nematode populations would be needed. Alternatively, other leguminous plants are less favourable reproductive hosts for root-knot nematodes (Timper et al. 2003) and may be used as a viable winter cover crop. Our results suggest that conservation tillage with winter leguminous covers and in-furrow application of a fertilizer, or increasing ground cover decreases thrips numbers and resulting plant damage in both cotton and peanuts. It would be necessary to determine if the results from our conservation tillage and cover crimson clover study are applicable to cotton systems with higher yields to determine if this may be a viable alternative to aldicarb use in dry-land cotton without significant root-knot nematode populations.

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